This article was published in the April 2001 issue of *Environment*.
Volume 43, Number 3, pages 8-18. Posted with permission.

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Urban environmental managers need to find
to address the many ways climate change af
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ate Change and a Global City

Learning from New York

viable strategies
fects megacities,
sessment shows.

by Cynthia Rosenzweig and William D. Solecki

Often located on vulnerable coastlines and home to a rapidly growing percentage of the Earth's people, megacities are at the forefront of vulnerability and adaptation to and mitigation of climate change. As climate change impacts become more tangible and regional climate change forecasts improve, a dynamic is developing between climate change science and policy response in urban settings. Urban decision makers and managers face the challenge of devising new types of adaptations, adjustments, and mitigation strategies.

Such adaptations and adjustments may include physical modifications to infrastructure (e.g., higher seawalls and raised airport runways); changes in decisionmaking practices (e.g., increased use of management strategies with overlapping jurisdictions and longer timeframes); and far-reaching societal shifts (e.g., disinvestment in highly vulnerable coastal sites and increased support for at-risk populations of the poor and elderly). These new responses, in turn, will interact with the ongoing processes of ecological and societal transition in large urban zones, as well as with policies implemented to reduce greenhouse gas emissions.

Even while city managers find ways to reduce greenhouse gas emissions (the root cause of the projected climate change), they need to find ways to adapt to changing climate conditions because the gases already emitted into the atmosphere will cause some degree of warming. Thus, global cities will be adapting to and mitigating climate change at the same time.

This article investigates the impacts of climate variability and change on the New York City metropolitan region.[1] As a mature urban system, the region presents an excellent example of how megacities experience climate impacts and how global climate change is helping to forge a new paradigm of urban environmental management in these places. The recent Metropolitan East Coast (MEC) Regional Assessment,[2] carried out between 1998 and 2000, provides the case study for this investigation.[3]

Global climate models predict that in the 21st century New York will experience higher temperatures throughout the year, more heat waves in summer, rising seas, shorter recurrence periods for severe storms, and increased frequencies of drought and flooding. These climate shifts are likely to simultaneously inundate coastal wetlands, threaten vital infrastructure and water supplies, augment summertime energy demand, and directly and indirectly affect public health.

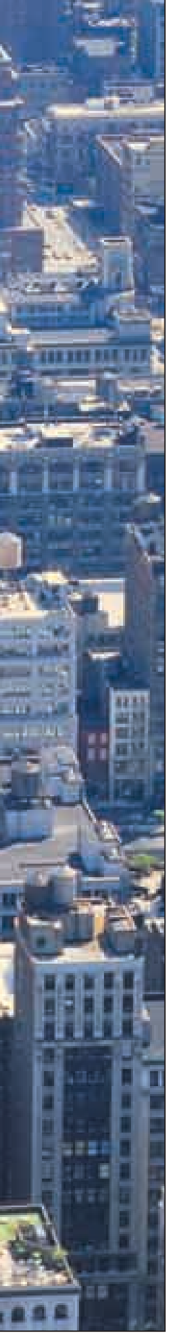
Given the region's position in the global urban hierarchy,[4] these concurrent and interactive impacts could have regional, national, and international implications: Because global cities are major sites of international capital and labor flows, climate change impacts are not limited by a city's boundaries. For example, a major climate-related disruption of the New York Stock Exchange would have reverberating impacts on global financial markets. Thus, transforming the urban management paradigm to better prepare for climate change will safeguard against negative feedbacks around the world.

Climate change may be the ultimate stress on a city where the dense population already puts tremendous demand on land and water resources.[5] The New York City metropolitan region—five boroughs and the adjacent 26 counties in New York, New Jersey, and Connecticut—is the quintessential urban agglomeration in the United States (see Figure 1 on page 11). Approximately 7.5 million people live in the city proper and more than 10 million live in the adjoining areas, creating a total population approaching 20 million.[6]

The regional landscape has been dramatically transformed, particularly in the older urban and suburban areas. Approximately 30 percent of the metropolitan land area has been fully converted to urban uses, with significant reduction in vegetative cover. The rate of conversion has accelerated even though the rate of population growth has slowed.[7] The U.S. Federal Emergency Management Agency estimates that the overall value of the region's built environment ranges in the trillions of dollars.[8]

Dense concentrations of people, like in midtown Manhattan, put an enormous demand on regional land and water resources. Climate change will further complicate urban human-environment interactions.

Environmental management is particularly problematic in large urban areas such as New York. Difficulties include the high demand for ecosystem services (e.g., clean drinking water must be provided for the region's population); the diversity of environmental problems (e.g., poor air quality, toxic waste dumps, and threatened wetlands); and their interconnectedness (e.g., eradicating mosquitoes associated with the West Nile virus brought extensive spraying with Malathion, a potentially carcinogenic pesticide). Furthermore, the diversity of the popula-



tion and a fractured political landscape make all policy discussions complicated, including those that relate to the environment.[9]

Like other large urban areas, the New York metropolitan region has spread far beyond the political boundaries of New York City and includes populations that represent often conflicting social and political agendas. Taken together, these factors undercut attempts to develop a regional governance ethos of sustainability.

How the New York metropolitan region, as one of the most developed in the world, will respond to the many-faceted demands of global climate change may be seen as the bellwether for other large cities on national and global scales.

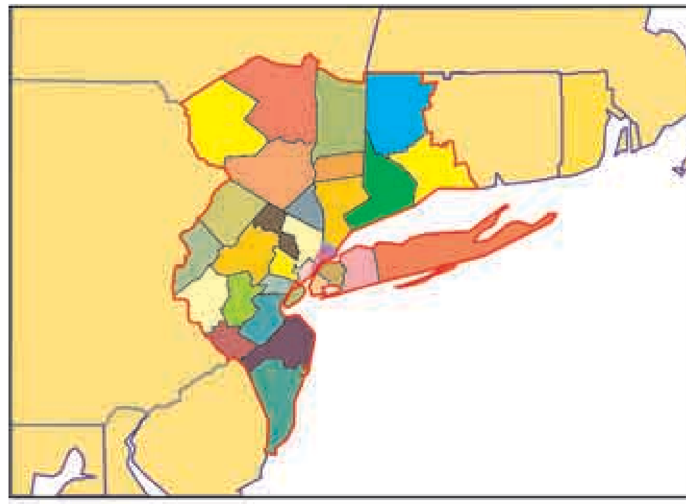
Regional Climate and Potential Change

In the MEC Regional Assessment, researchers and stakeholders used historical climate trends, current climate extremes, and future climate change scenarios to study climate-society interactions. Future climate change scenarios are based on current climate trends and projections of global climate models. These scenarios are defined as plausible combinations of climatic conditions that may be used to project possible impacts created by climate change and to evaluate responses to them.

Climate change is already occurring in the New York City region. Over the past century, annual temperature has increased by nearly 2 degrees Fahrenheit (F) after the effects of the urban heat island have been removed (see Figure 2 on this page). (Buildings and concrete absorb heat during the day and release it at night, making cities warmer than surrounding areas.) Warming since 1950 may be at least partially attributed to anthropogenic increases in greenhouse gases.[10] Precipitation levels in the MEC region have increased slightly—an average of about 0.1 inch per decade over the past century.

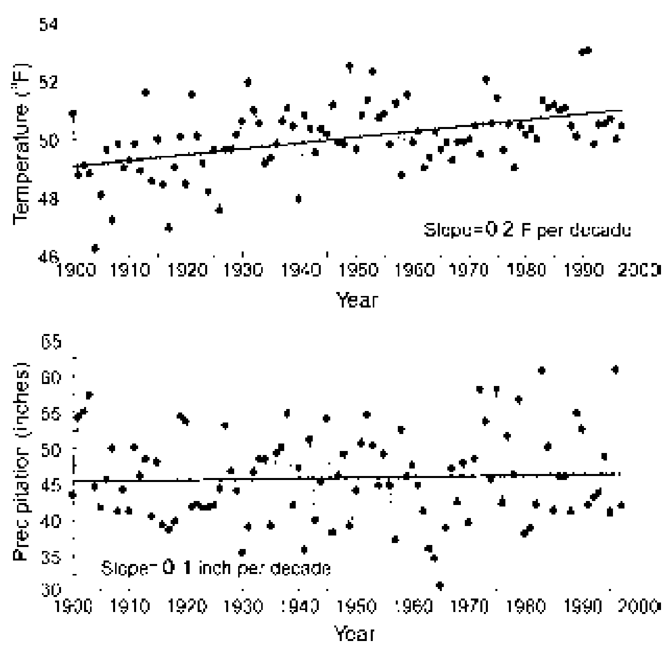
The two years of the MEC assessment saw striking examples of the impacts of climate extremes, including heat waves, droughts, and floods. During the summer of 1999, there were heat waves and associated blackouts in the lower socioeconomic neighborhoods of northern Manhattan and the South Bronx.

Figure 1. The New York metropolitan region



SOURCE: C. Rosenzweig and W. D. Solecki, 2001.

Figure 2. Trend in average temperature and precipitation in the New York metropolitan region, 1900–1999



NOTE: Data are averaged over 23 stations and have been corrected for the urban heat island effect.

SOURCE: C. Rosenzweig and W. D. Solecki, 2001.

Increased use of air conditioning in hot weather often results in blackouts because extra stress is placed on energy sources. An intense summer drought may have contributed to the fatal outbreak of the West Nile virus.[11] In September 1999, Tropical Storm Floyd brought large-scale flooding in northern New Jersey and southern New York State.

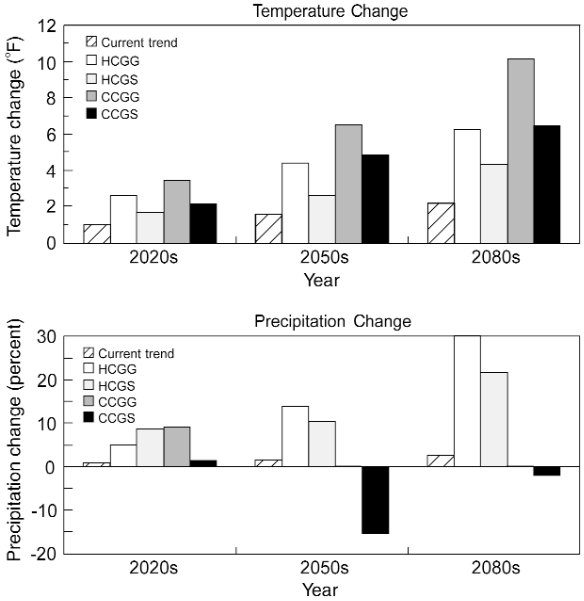
Climate Change Scenarios

Climate change projections for New York City have been derived from global climate models (GCMs). These mathematical models simulate future temperature and precipitation changes in response to projected increases in carbon dioxide (CO_2) and other greenhouse gases and trends in sulfate aerosols. Global climate models are mathematical formulations of the processes that comprise the climate system, including radiation, energy transfer by winds, cloud formation, evaporation and precipitation of water, and transport of heat by ocean currents. These equations are solved for the atmosphere, land surface, and oceans over the entire globe. The models are used to simulate the climate system's future responses to additional greenhouse gases emitted into the atmosphere by human activities. GCMs project climate responses at relatively coarse-scaled resolutions (roughly 2.50 degrees latitude by 3.75 degrees longitude), from which regional scenarios for the New York City study area were linearly interpolated. Time periods for the analysis are the 2020s, the 2050s, and the 2080s.

The GCMs are those of the U.K. Hadley Centre[12] and the Canadian Climate Centre,[13] with sensitivities to doubled CO_2 of 4.7 degrees F and 6.3 degrees F, respectively. (Sensitivity is defined as the global mean temperature change resulting from a doubling of atmospheric carbon dioxide in a global climate model simulation.) The GCM transient simulations are forced with a 1 percent per year increase of equivalent CO_2 concentration based on the "business-as-usual" emission scenarios of the Intergovernmental Panel on Climate Change.[14] These simulations are performed with sulfate aerosols and also without them (sulfate aerosols, which are formed from industrial processes, tend to cool surface temperature because they reflect and scatter solar radiation).

Projected changes in New York City's annual temperature and precipitation for the four GCM scenarios and for continued current trends are shown in Figure 3 on this page. The GCM-projected temperature changes are greater (from 4.4 to 10.2 degrees F by the 2080s) than those projected by current trends (about 2.2 degrees F in the 2080s) because the GCM scenarios account for increasing feedbacks from greenhouse gases that warm the Earth's atmosphere. There are also discrepancies between the GCM scenarios and current trends in magnitude and direction of precipitation forecasts: They show that precip-

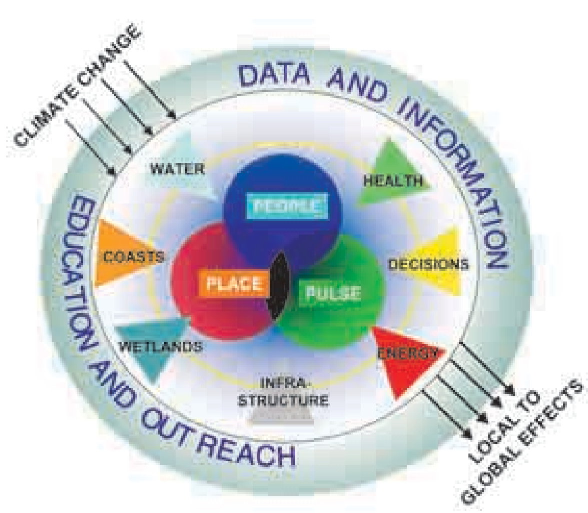
Figure 3. Projected temperature and precipitation change due to increasing greenhouse gases for the New York metropolitan region



NOTE: Projections are from the Hadley Centre (HC) and Canadian Climate Centre (CC) global climate models with (GS) and without (GG) sulfate aerosols.

SOURCE: C. Rosenzweig and W. D. Solecki, 2001.

Figure 4. Framework for the Metropolitan East Coast Regional Assessment



SOURCE: C. Rosenzweig and W. D. Solecki, 2001.

New York City's Brooklyn Bridge spans the East River. Augmented storm surges associated with sea-level rise will increase the risk of damage to infrastructure along the coast.

itation will change between -15 and +30 percent, indicating hydrological uncertainty in future decades.

Interactive Impacts

Using the climate change scenarios, the seven sector studies of the MEC Regional Assessment analyzed potential impacts on coasts, infrastructure, wetlands, water supply, public health, energy demand, and institutional decisionmaking. The sector studies were embedded in a conceptual framework that encouraged the consideration of how three interacting elements of global cities react and respond to climate variability and change (see Figure 4 on page 12). The three elements are people (i.e., socio-demographic conditions), place (i.e., physical and ecological systems), and pulse (i.e., decisionmaking and economic activities). As results from the individual sector studies were analyzed, it became clear that climate change impacts in cities will be simultaneous, multidimensional, and interactive.

Sea-Level Rise, Coastal Infrastructure, and Salt-Marsh Wetlands

Sea-level rise associated with global warming will result in widespread impacts on a region as closely linked to the ocean-land interface as New York City. The current rate of sea-level rise is approximately 0.1 inch per year, with some regional variation.[15] About half of this rate is associated with regional land subsidence linked to isostatic rebound of formerly glaciated land to the north (land to the north, which was under ice 20,000 years ago, continues to rebound, while most of the Atlantic Coast is subsiding); the other half is associated with the observed change in global mean temperature, which rose more than one degree F between 1900 to 2000. Climate change will foster further sea-level rise because of increased melting of glacial ice (e.g., the Greenland icesheet) and thermal expansion of the upper layers of the ocean.

The key threat of sea-level rise is its effect on storm surges. Heightened storm surges associated with future hurricanes and nor'easters (strong winter extra-tropical cyclonic storms) will cause the most significant damage (see Figures 5 and 6 on pages 15 and 16). Given the projected rates of sea-level rise, some scientists have estimated that under a worst-case scenario, by the 2080s a coastal storm event comparable to a 100-year flooding could occur every 3–4 years,[16] and in more extreme and uncertain estimates, a 500-year flooding event could occur every 50 years.[17] Even a more moderate compression of the extreme flooding interval can have large impacts.

Many of the region's most significant infrastructure facilities will be at increased risk to damage resulting from augmented storm surges.[18] The default public policy of placing necessary yet locally unwanted land uses on marginal lands (such as transportation infrastructure across and along the edges of wetlands, bays, and estuaries) may engender some unintended consequences, such as the increased disruption of key infrastructure components or the need for their relocation. The Hackensack Meadowlands in northern New Jersey is a good example; the low-elevation, degraded wetland has dozens of vulnerable infrastructure features, such as the airport, port facilities, pipelines, and highways.

A different vulnerability is exhibited by the region's salt-marsh wetlands. Under natural conditions, wetlands respond to sea-level rise through accretion and inmigration. However, many of the wetlands in the New York metropolitan area can no longer respond this way because of reductions in sediment input and upland migration sites resulting from extensive land development in the coastal zone. The few remaining coastal wetlands provide critical habitats for local and migratory animals, particularly waterfowl species. Wetlands also protect inland development from storm surges and act as water purifiers by natural filtration.

Severe wetland loss in the region's remnant coastal marshlands has already been recorded. For example, recent research indicates that salt-marsh islands in the Jamaica Bay Wildlife Refuge, part of the Gateway National Recreation Area, decreased approximately 10 percent in size between 1959 and 1998.[19] Given that much of the decline in sediment input took place in the early decades of the 20th century, a significant amount of this loss may have resulted from the already occurring sea-level rise.

Future scenarios illustrate that the rate of sea-level rise is likely to continue to exceed the accretion rate of wetlands, causing even more rapid disappearance of wetlands. This outcome coupled with impacts on infrastructure portends a coastline increasingly at risk in the future (see the box on page 17).

Water Supply: Local and Regional Issues

Climate change and increased climate variability present management challenges for the New York metropolitan region's water supply systems. First, there is uncertainty in how the total amount of precipitation might change in the future. In addition, there will be greater hydrologic variability. The potential for extended droughts followed by rainy periods is present in many of the climate change scenarios and associated Palmer Drought Severity Indices (PDSI) for the region. (The PDSI is a meteorological measure of moisture supply and demand used to assess the severity of dry or wet spells.) Finally, expected sea-level rise is likely to interact with the region's water supply infrastructure.

Pumping stations, water quality treatment facilities, and intake and outflow sites are vulnerable to storm-surge flooding. There is also increased threat of salt-water intrusion into regional ground-water supplies and at surface-water withdrawal sites, such as the Chelsea pump station on the Hudson River—a source of supplemental water during periods of extreme drought.

The region's recent weather provides a good illustration of projected patterns. Although the rainfall in 1999 was average (about 45 inches), the region experienced a rainy winter and early spring, then a severely droughty late spring and early- and mid-summer, followed by an extremely rainy late summer and early fall, and finally a moderate end-of-year. Water supply systems that did not have the capacity to store the early rains began to call for drought emergency measures by midsummer, only to switch abruptly to emergency flood measures due to the devastation caused by Tropical Storm Floyd, which brought as much as 12 inches of rain in northern sections of the region in September.

Current research indicates that the New York City water supply system—the largest in the study region and one of the largest in the world—should be able to respond to the expect-

Climate change is projected to bring greater hydrologic variability, including more frequent extreme rainfall events.

ed increases in annual temperature and their effects on the water supply via evapotranspiration as well as greater variability in rainfall in the near term.[20] Responses to projected salt-water intrusion and the longer term need further study. However, the shifts in climate might overwhelm the response capacity of smaller systems within the MEC region, such as those in New Jersey and Long Island. Water supply experts have called for the evaluation of enhanced intra- and inter-regional water distribution protocols, which could potentially include diverting Delaware River water from the west to reduce vulnerability to drought in the MEC region and vice versa.[21]

Public Health and Energy Demand

Inequity and the spatial and demographic unevenness of climate change impacts are probably no better expressed than in the risks to the public health sector in urban regions. Populations in such urban areas as New York City will experience increased exposure to heat stress conditions, greater potential of water-borne or vector-related disease outbreaks, and higher concentrations of secondary air pollutants, resulting in higher frequency of respiratory ailments and attacks (e.g., asthma).[22]

Populations currently at risk, including the poor, immuno-compromised, elderly, and very young, will be the most vulnerable. The 1995 census estimates reported that about 24 percent of New York City's population lives below the poverty line.

Interactions between electric energy demand and health effects will also occur under conditions of climate change because of the connections between climate warming, increased energy demand, electricity blackouts or brownouts (a blackout is a total disruption of electrical power, and a brownout involves a partial reduction of electrical power, causing lights to dim or "brown out"), and resulting health stress. These connections are evident among the elderly urban poor who have limited access to air conditioning and are physiologically at heightened risk of heat stress. Heat stress will become especially problematic for this population if electricity outages, exacerbated by heightened demand for air conditioning in hotter conditions, occur more frequently in the future (see Figure 7 on page 16).

Although climate change will dampen the winter demand for energy, this will be far offset by an estimated increase in summer electricity demand.[23] Summer demand could be especially strong during summer heat waves as illustrated in the set of four successive heat waves that hit the region from late June through early August 1999. The temperature rose to more than 90 degrees F for 27 days during the period and to more than 100 degrees F twice. The climate change scenarios project that the average number of days exceeding 90 degrees F (13 days in the current climate) will increase by 2–3 times by the 2050s.

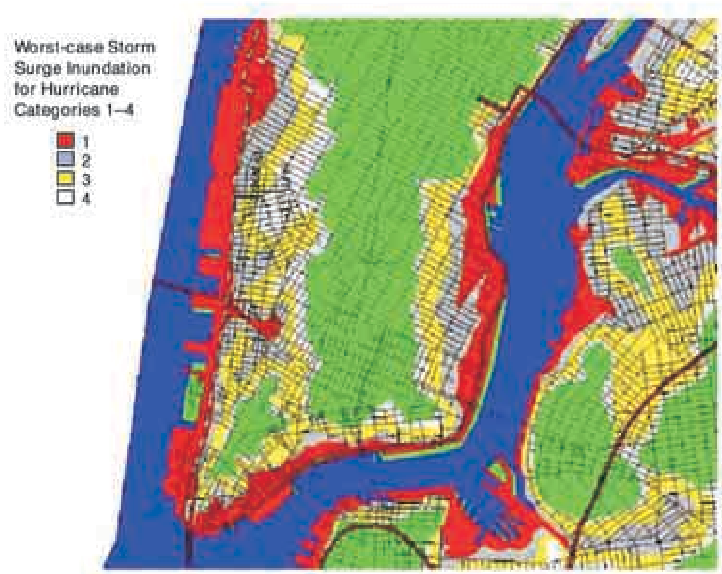
The peak electrical demand recorded in the region occurred on 6 July 1999. Brownouts and an extended blackout occurred in the primarily minority neighborhoods of upper Manhattan and the South Bronx. Residents and local politicians argued that the blackout revealed that the local power authority had not properly maintained the equipment serving the neighborhoods, putting populations of color at risk.[24] These events might foreshadow future extreme events and associated real and perceived inequity.

Heat waves will also exacerbate secondary air pollution problems in the region. Peak electricity demand and fossil fuel burning during heat waves will result in increases of primary air pollutants (e.g., nitrogen oxides) and secondary pollutants (e.g., ozone). Increased concentrations of such pollutants in turn will result in higher numbers of respiratory-related attacks and hospitalizations.[25]

Barriers to Climate Change Responses

What limits effective regional response to the interactive impacts described above? Some barriers reflect problems inherent in urban environmental management.[26] In a region of

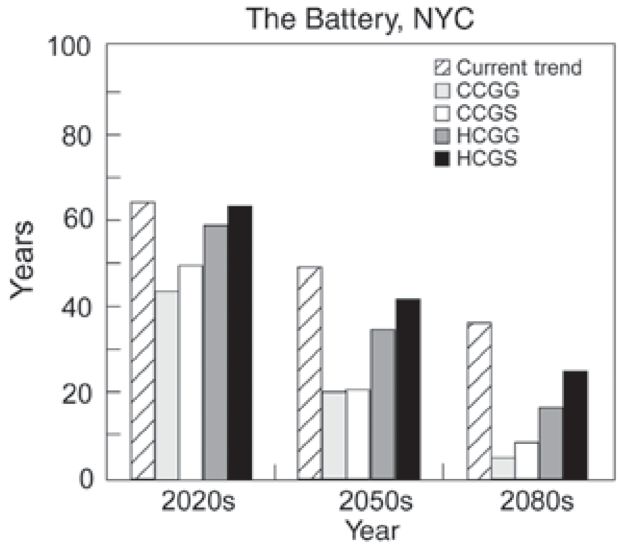
Figure 5. Storm surge inundation in lower Manhattan for Saffir-Simpson categories under current climate conditions



NOTE: The Saffir-Simpson hurricane scale is used to rate on a 1–5 scale the intensity of hurricanes at a given time. Category One hurricanes have the weakest winds (75–95 mph), and Category Five hurricanes have the strongest winds (more than 155 mph).

SOURCE: U.S. Army Corps of Engineers, Federal Emergency Management Agency, National Weather Service, and NY/NJ/CT state emergency management agencies, *Metro New York Hurricane Transportation Study, Interim Technical Data Report* (1995).

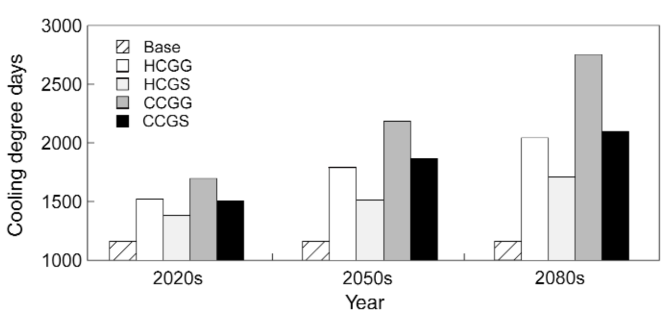
Figure 6. Projected change in 100-year flood return period due to increasing greenhouse gases for the New York metropolitan region



NOTE: The Battery is the southern tip of Manhattan overlooking the New York harbor. Projections are from the Hadley Centre (HC) and Canadian Climate Centre (CC) global climate models with (GS) and without (GG) sulfate aerosols.

SOURCE: V. Gornitz, 2001.

Figure 7. Cooling degree days change due to increasing greenhouse gases for the New York metropolitan region



NOTE: The base period is 1979–1996. Degree days are calculated using a value of 65˚F. Projections are from the Hadley Centre (HC) and Canadian Climate Centre (CC) global climate models with (GS) and without (GG) sulfate aerosols.

SOURCE: D. Hill and R. A. Goldberg, 2001.

more than a thousand jurisdictions, home rule and a splintered political landscape characterize the New York metropolitan region. In addition to the federal government and several regional organizations, the region is divided jurisdictionally into 3 states, 31 counties, and hundreds of municipalities.[27] In this setting, short-term political concerns tend to dominate. Policy responses to climate change are also hampered by the generally reactive nature of management organizations. Institutional action is often directed at immediate and obvious problems; issues that might emerge fully only after several decades are perceived as less pressing.

Another set of barriers reflects the complexities associated with the nature of the climate change issue itself. In most cases, environmental and natural resource agencies simply do not expect to experience the dynamic and multidimensional impacts that the MEC Regional Assessment has identified. The scientific uncertainty regarding regional manifestations of climate change also makes local responses difficult. Currently, institutional decision makers are not sure how, when, and where climate change–related impacts might emerge in the region. All these conditions challenge decisionmaking agencies and institutions to address some of the basic assumptions regarding how the systems they oversee are managed as they respond to this significant planetary phenomenon.

Linking Future Climate Change to Present-Day Urban Environmental Management

Given these barriers, how can environmental managers in urban regions start to respond to the potential challenges and opportunities of climate change, and how can they bring the issue into their everyday decisionmaking processes? These changes are part of a transformation of the urban environment management paradigm. Several types of bridges can be built at the conceptual and operational levels.

At the conceptual level, decision makers must be proactive with respect to potential climate change and variability, responsive to potential environmental changes on longer time horizons, and flexible in the face of increased uncertainty. At the operational level, current major capital reinvestment activities and structural shifts in management regimes in the MEC region provide excellent pathways for integration of climate change adaptation into stakeholders' decisionmaking practices.

Several initiatives will help build the necessary foundation for these pathways to be followed. These include education and outreach programs, enhanced methods for defining and entraining potential climate change impacts into planning decisions, and increased interagency communication and cooperation.

Climate Awareness Program

As an education and outreach component, a regional climate awareness program would be effective to inform decision makers and the general public about the nature of current climate processes, lessons learned in responding to climate extremes, and future climate change. Enhanced training of weather forecasters in the region about climate change along with climate awareness web sites or other easily accessible sources of updated information would facilitate this process. In the case of the MEC Regional Assessment, the Center for International Earth Science Information Network and Columbia Earth Institute are in the process of developing an ongoing climate awareness web site for the region.[28]

Climate Impact Indicators

Through communication with stakeholders in the course of the MEC Regional Assessment, researchers recognize that impacts of potential climate change have to be put into the discourse of the everyday decisionmaking process. Rates of possible sea-level rise, temperature shifts, and precipitation shifts are relatively remote to the average decision maker and region resident. Impacts must be put into contexts that are meaningful. For example, sea-level rise will mean an "x" amount of increased costs of beach renourishment, and temperature increases will mean a "y" increase in acute asthma attacks. The development of a set of cost-based, urban-focused climate change impact indicators would make a significant contribution, as would monitoring ongoing trends in urban ecosystem impacts, such as wetland loss.

Interagency Climate Task Force

Increased intra- and inter-sectoral communication amongst agencies and institutions would also increase the response capacity of local decision makers to potential climate change impacts. This kind of enhanced communication would allow decision makers to identify potential problems and to define common solutions. Examples of the general utility of these intra-sector interactions are already present in the New York metropolitan region. The Southeastern New York Intergovernmental Water Supply Advisory Council is a volunteer, nonregulatory group of water supply managers who communicate on common problems and planning initiatives.

Intersectoral working groups are far fewer. Such groups are critical for addressing the impacts that cut across sector lines. The regional assessments, as part of the recent U.S. National Assessment of the Potential Consequences of Climate Variability and Change program, represent limited examples of this phenomenon because the assessment teams included representatives from a variety of local, state, and national stakeholder institutions, agencies, and businesses. Through the regional assessment process, initial intersectoral discussions evolved both within the government and business stakeholder groups and across the two groups. In metropolitan regions, this type of interaction is especially important given the highly integrative nature of the urban environment problems, such as the links between public health and energy demand and the links between the ecological and infrastructural components of the coastal environment. Interagency task forces developed as part of regional watershed management activities can serve as valuable examples of how to develop climate change–related groups.

Coastal Communities and Ecosystems in 2050

Standing on the ocean's edge in 2050, a citizen looking out over the New York harbor toward lower Manhattan will see a shoreline under siege. Significant change will be under way, because coastal communities are among the most vulnerable sites to changing sea levels and more frequent flooding from storm surges.

Although it is impossible to know if the region will experience a catastrophic storm and flooding event by 2050, there will be a greater frequency of what we now know as 25-year and 50-year storms. Shoreline homes, airports, fuel storage facilities, and ecosystems will be flooded ever more repeatedly.

Coastal wetlands, such as the Jamaica Bay salt-marshes, are likely to be the "canary-in-the-coal-mine" for global warming, showing the most manifest evidence of loss associated with sea-level rise. Assuming that limited opportunity has been provided for a retreat inland, the remaining fringe of wetlands in the region would be in clear decline, causing a ripple of other ecological effects, including the loss of critical bird and aquatic habitats.

By 2050, the region's residents will be well-attuned to the impacts of climate change. Their response to the threat up until that time will determine the magnitude and condition of the overall consequences. Even if the "big storm" has not hit by 2050, management institutions and agencies operating in the region already should have prepared for such a storm by protecting the changing coast.

The first decades of the new millennium will have been spent creating appropriate flood maps and flood frequency estimates, wetland conservation and restoration projects, coastal building code regulations, beach renourishment time-tables, insurance policy mandates, and flooding response protocols. Such activities will be necessary to take into account potential climate change and its effects on the region's human, physical, and ecological coastal assets.

The Climate Change Challenge

Climate change will fundamentally affect the people, place, and pulse of large cities. Heightened frequencies of

New York City is a global city at the water's edge.

storm surges will damage major infrastructure juxtaposed to already threatened coastal wetlands; health impacts cannot be separated from the impacts of augmented heat waves on energy demand. The complex nature of potential climate change impacts in urban regions poses tremendous challenges to urban environment managers to respond cooperatively, flexibly, and with far longer decisionmaking time frames than currently practiced. Given the already fragmented nature of urban environments and jurisdictions, the political and social responses to the global climate issue in cities should begin at once.

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Rosenzweig and Solecki are currently coleading the Metropolitan East Coast Regional Assessment for the U.S. National Assessment of the Potential Consequences of Climate Variability and Change (http://metroeast_climate.ciesin.columbia.edu).

The authors thank Michael MacCracken and Lynne Carter of the National Assessment Coordination Office of the U.S. Global Change Research Program for their support of the Metro East Coast Regional Assessment. Funding for this project came from the U.S. National Science Foundation, Columbia Earth Institute, and U.S. Environmental Protection Agency, Region II.

NOTES

1. Mitigation strategies for global cities are being addressed in follow-on studies.

2. The MEC is one of the 18 regional assessments of the U.S. National Assessment of the Potential Consequences of Climate Variability and Change, sponsored by the U.S. Global Change Research Program. The Columbia Earth Institute was the lead institution of the MEC Regional Assessment.

3. C. Rosenzweig and W. D. Solecki, eds., *Climate Change and a Global City: The Metropolitan East Coast Regional Assessment*, Metro East Coast Report of the U.S. National Assessment of the Potential Consequences of Climate Variability and Change (New York: Columbia Earth Institute, 2001).

4. S. Sassen, *The Global City: New York, London, Tokyo* (N.J.: Princeton University Press, 1991); S. Sassen, *Cities in a World Economy* (London: Pine Forge Press, 1994); and M. E. Crahan and A. Vourvoulias-Bush, eds., *The City and the World: New York's Global Future* (New York: Council on Foreign Relations, 1998).

5. Aspen Global Change Institute, *Climate Change and Cities* (Aspen, Colo.: Aspen Global Change Institute, forthcoming 2001).

6. R. Yaro and T. Hiss, *A Region at Risk: The Third Regional Plan for the NY/NJ/CT Metropolitan Area* (New York: Regional Plan Association, 1996).

7. Ibid.

8. Hazus, *Federal Emergency Management Agency Tool for Estimating Earthquake Losses*, NIBS/FEMA, Washington, D.C., 2 basic CDs (Eastern and Western United States) and user manual, plus 1 CD per state (Windows OS).

9. J. K. Mitchell, ed., *Crucibles of Hazards: Mega-Cities and Disasters in Transition* (Tokyo: United Nations University Press, 1999).

10. T. R. Karl, R. W. Knight, D. R. Easterling, and R. G. Quayle, "Trends in U.S. Climate during the Twentieth Century," *Consequences* 1, 3–12; and J. T. Houghton et al., *Climate Change 1995: The Science of Climate Change: Contribution of Working Group I to the Second Assessment Report of the Intergovernmental Panel on Climate Change* (U.K.: Cambridge University Press, 1996).

11. Carried by *Culex pipiens* mosquitoes and local birds such as crows, the West Nile virus caused 62 human cases of encephalitis and seven deaths in the New York area between July and September 1999.

12. T. Johns et al., "The Second Hadley Centre Coupled Ocean-Atmosphere GCM: Model Description, Spin-Up, and Validation," *Climate Dynamics* 13, 103–34.

13. G. Flato, et al., *The Canadian Centre for Climate Modeling and Analysis Global Coupled Model and Its Climate* (The Canadian Centre for Climate Modeling and Analysis, Atmospheric Environment Service, University of Victoria, British Columbia, 1999).

14. IPCC, *Climate Change 1995: Impacts, Adaptations, and Mitigation of Climate Change: Scientific-Technical Analysis* (U.K.: Cambridge University Press, 1996).

15. V. Gornitz, "Monitoring Sea Level Change," *Climate Change* 31, 515–44 (1995).

16. V. Gornitz, with contributions from S. Couch, "Sea-Level Rise and Coasts," in Rosenzweig and Solecki, eds., note 3 above.

17. K. H. Jacob, N. Edelblum, and J. Arnold, "Infrastructure," in Rosenzweig and Solecki, eds., note 3 above.

18. Ibid.

19. E. K. Hartig, F. Mushacke, D. Fallon, and A. Kolker, "Wetlands," in Rosenzweig and Solecki, eds., note 3 above.

20. D. C. Major and R. A. Goldberg, "Water Supply," in Rosenzweig and Solecki, eds., note 3 above.

21. G. Hansler and D. C. Major, *Climate Change and the Water Supply Systems of New York City and the Delaware Basin: Planning and Action Considerations for Water Managers*, Extended Abstracts Proceedings: Specialty Conference on "Potential Consequences of Climate Variability and Change to Water Resources of the United States," American Water Resources Association Meeting, Atlanta, Ga., 10–12 May 1999, 327–30.

22. P. L. Kinney, D. Shindell, E. Chae, and B. Winston, "Public Health," in Rosenzweig and Solecki, eds., note 3 above.

23. D. Hill and R. A. Goldberg, "Energy Demand," in Rosenzweig and Solecki, eds., note 3 above.

24. J. Wilgoren and K. R. Roane, "Cold Showers, Rotting Food, the Lights, Then Dancing," *New York Times*, 8 July 1999, B1, B4.

25. Kinney, Shindell, Chae, and Winston, note 22 above.

26. L. H. Gunderson, C. S. Holling, and S. S. Light, eds., *Barriers and Bridges to the Renewal of Ecosystems and Institutions* (New York: Columbia University Press, 1995).

27. R. Zimmerman and M. Cusker, "Institutional Decision-Making," in Rosenzweig and Solecki, eds., note 3 above.

28. See http://metroeast_climate.ciesin.columbia.edu.